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Comparison of two contemporary rotary systems in a pre-clinical student course setting

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Key words: instrumenting system, students, simulated root canals, 3D-printed teeth

Running head: Comprehensive comparison of rotary systems

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Abstract

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Methodology Undergraduate dental students (n = 44) prepared mesiolingual canals of 3D-printed mandibular molar replicas (RepliDens, Zurich, Switzerland). The HyFlex and BioRace rotary systems, both previously unknown to the students, were used according to manufacturers' guidelines after a short theoretical introduction. For comparison, a first-generation rotary system (ProFile .04), which the students knew from their previous education, was then used in a third RepliDens. Questionnaires were issued to note subjective experiences immediately after instrumentation. Objectively, time to instrument to size 40, .04 taper and shaping outcomes were analysed. Categorical data was compared using Chi-squared and Fisher's exact tests, numerical data according to goodness of fit to the normal distribution, $P < 0.05$.

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Conclusions HyFlex and BioRace had perceived and quantifiable strengths and weaknesses. Both systems were equally liked by the students, and preferred over the ProFile first-generation rotary system.

Introduction

Rotary instrumentation gained wide popularity in the 1990s, when the first rotary instruments made from nickel-titanium became available (Glosson *et al.* 1995). Today, many engine driven nickel-titanium rotary systems are on the market; each with specific design, sequence, nickel-titanium alloy, and taper (Peters & Paqué 2010, Haapasalo & Shen 2013). First-generation rotary systems were used in a crown-down sequence, and had negative rake angles in an attempt to avoid taper lock and prevent transportation of the canal system, respectively (Kavanagh & Lumley 1998) In contrast, more recent systems frequently use a full-length approach from the second rotary instrument in the system, and feature actively cutting blades. They avoid taper lock by changing the taper between instruments in the sequence, or feature instruments with varied taper (Peters 2004). Based on studies on extracted teeth and instruments operated by one single experienced (and thus not inherently objective) dentist, actively cutting single-length rotaries are safe to use, reach their shaping goal quickly, and do not necessarily transport the original canal anatomy (Paqué *et al.* 2011, Bürklein *et al.* 2013). However, the material tests performed to reach these conclusions have been questioned regarding their scientific value (Hülsmann 2013). Indeed, performance of root canal instruments in clinic may be related to many more factors then their mere shaping ability in the hands of an expert. Moreover, the features that make a specific instrumenting system preferable over others to novice users may be manyfold. In this context it should be emphasized that every dentist thinking about implementing a new system in his or her office usually lacks experience regarding its use. It may thus be a good idea to test systems by novices, e.g. in a student-course setting, preferably with students who have basic knowledge and skills, yet are not yet influenced by dental product marketing or clinical experience (Himel *et al.* 1995, Sonntag *et al.* 2003).

Therefore, the purpose of the present study was to compare two contemporary actively cutting single-length systems by fourth-year students, who had previously been trained to use hand

and first-generation rotary instruments. Subjective evaluation was performed using a questionnaire, objective assessment was conducted by comparing shaping outcomes. To avoid high variance in initial canal configuration, 3D-printed tooth replicas were used for the first time in this study. To put results in perspective, student opinions and shaping outcomes on/with these newer systems were related to the first-generation rotary system they had been trained on.

Materials and methods

Students

Forty-four fourth-year dental students (18 males, 26 females) without clinical experience in Endodontology, but having completed preclinical training and theoretical education, participated. Six students were on their second educational track in dentistry and were between 30 and 37 years of age, the rest were between 21 and 29 years old. At this point, all of these students had similar theoretical and practical experience with hand and first-generation rotary instrumentation using the balanced force technique (Roane *et al.* 1985) and the rotary ProFile .04 system (Dentsply Maillefer, Ballaigues, Switzerland). These concepts had been taught separately and in combination. In more detail, prior to this study, the students had instrumented a minimal requirement of 2 canals in plastic blocks and 1 two-rooted premolar using hand instruments and 2 canals in plastic blocks and 1 molar using rotaries (ProFile, Dentsply Maillefer). Teeth were treated in a real-tooth jaw model in the dummy head. Despite the fact that natural anatomy varies, they were familiar with the instrumentation of curved canals.

Experimental teeth

The 3D-printed teeth (n = 146, 3 × 44 + 14 positive controls, see below) used in this study were obtained from a commercial source (Mandibular Molar 1 – opaque, smartodont llc, Zürich, Switzerland). The replicas all represented a mandibular left molar with 2 joining mesial canals (Fig. 1). The mesiolingual canal was used for this study. This canal had a length of 24 mm, a Schneider curvature of 42° (Schneider 1971), and a curvature radius of 7.2 mm (Pruett *et al.* 1997). Mesiolingual canal curvature before and after instrumentation was determined in each tooth using a modified version of the method described by Luiten *et al.* (1995). A size 10 K-file (Dentsply Maillefer) was inserted to working length (23.5 mm), and the tooth with the file was digitally (Digora, Soredex, Tuusula, Finland) radiographed in a standardized manner. Radiographs were taken from the buccal aspect at a pre-defined angle, distance, exposition time, and voltage (0.1 t/s, 65 kV, 8 mA) in a standardized radiography box (Irix CCX, Trophy, Marne La Vallée, France). A special holder (Fig. 1) was fabricated from a wooden board and a mould consisting of a polysiloxane putty (Lab-Putty, Coltène/Whaledent, Altstätten, Switzerland) and a vinyl polysiloxane impression material (President Plus, Coltène/Whaledent). This holder allowed exact repositioning of the teeth in the radiography box. Measurements were performed using the ImageJ software (ImageJ 1.47v, National Institute of Health, Bethesda, MD, USA). Canal curvature was expressed as the angle obtained from inserting a straight line through the apical 3 mm of the instrument against a counterpart that went in the direction of the shaft of the instrument (Fig. 1). To enhance the precision of angle determination, images were digitally magnified. The canals were shown to have an initial angle of curvature between 59.4° and 61.3° (mean ± SD = 60.2° ± 0.5°). The error of measurement was determined by measuring the angle of the mesiolingual canal in the same 3D-printed molar 10 times. The standard error of this measurement was 0.1°, and consequently, canal curvatures are presented to 1 digit. Each tooth was numbered, so that the canal curvature after instrumentation could later be compared to the initial situation.

Positive control for canal transportation

As a positive control the mesiolingual canal of 14 of the 3D-printed molars was instrumented using Hedström files (Dentsply Maillefer) to a size 40 instrument by one investigator (PB). This was done to assess maximal transportation of the canal in the 3D-printed molar under investigation that could be achieved by cautious instrumentation using a system that is known to transport canals (Briseño & Sonnabend 1991). Starting from a size 15 instrument to working length the canals were gradually enlarged by winding the instruments to working length and then pulling them gently from the canal. Excessive force and multiple push-pull motions were avoided. Canals were irrigated with 1 mL of tap water between instruments using a side vented 30-gauge irrigation tip (Hawe Irrigation Probe, Kerr Hawe, Bioggio, Switzerland).

Instrumentation

Prior to the practical part of this study, students received a theoretical introduction of 40 min, covering the instructions for both instrument systems under investigation: HyFlex (Coltène/Whaledent) and BioRace (FKG Dentaire, La Chaux-de-Fonds, Switzerland). In addition, students obtained flow charts that could be used during the experiment, depicting each step for each system. These flow charts were previously discussed with and approved by the manufacturers. Each student prepared one canal using the HyFlex and one canal using the BioRace system. Because the names of both these systems are suggestive, the students were blinded regarding their brands. HyFlex was designated as System A in the introduction, on the flow chart, and in the questionnaire. BioRace was designated as System B. Reference points, i.e. mesiolingual cusp tips on the 3D-printed molars, were marked with a waterproof pen to avoid instrumentation of the false canal. Every canal was instrumented with new instruments provided by the respective manufacturers. Half of the students started with System A and the others with System B. Thereafter, the second 3D-printed tooth was instrumented with the other system.

The working length of the canals was set at 23.5 mm, which was 0.5 mm from the apical foramen. The working length of each instrument was set by the students prior to the start of treatment and was checked during the course of treatment. Students were instructed to rinse with 1 mL of tap water after each instrument using a plastic syringe with a side vented 30-gauge irrigation tip (Hawe Irrigation Probe). The tip was inserted as deeply as possible into the root canal without binding. All instruments were 25-mm long and were set into permanent rotation using a counter-angle hand piece (Dentsply Maillefer) powered by a torque-controlled electric motor (XSmart, Dentsply Maillefer). Rotational speed and torque limit were set according to manufacturers' instructions: System A (HyFlex) 500 rpm and 2.4 N/cm; System B (BioRace) 600 rpm and 1 N/cm, ProFile 250 rpm and 1 N/cm. The preparation sequences were as follows:

System A (HyFlex)

The canal was scouted with a size 10 K-file (Dentsply Maillfer). All rotary instruments were used without pressure in a pecking motion. The first instrument (size 25, .08 taper) was used to enlarge the coronal and middle part of the canal and was removed when resistance occurred. A glide path to a size 15 K-File was then performed manually to full working length of 23.5 mm. Subsequently, the second (size 20, .04 taper) and all following rotary instruments (size 25, .04 taper, size 20, .06 taper, size 30, .04 taper, and size 40, .04 taper) were used to full length and were removed once the canal was negotiated to working length. In case resistance occurred a hand file (size 15, .02 taper or size 20, .02 taper) was used to negotiate the canal, and the student had to repeat to the previous step.

System B (BioRace)

The canal was also first scouted with a size 10 K-File. All rotary instruments were advanced with four pecking motions and slight pressure. The first instrument (BR0, size 25, .08 taper) was used to enlarge the first 4-6 mm of the canal and was then removed. A glide path of size 15 was performed manually using a K-file to full working length of 23.5 mm. Thereafter the second (BR1, size 15, .05 taper) and all following rotary instruments (size 25, .04 taper, size 25, .06 taper, size 35, .04 taper, and size 40, .04 taper, designated BR2 to BR5) were brought to full length and were removed once the canal was negotiated. If full working length was not achieved after 4 pecking motions, the instrument was removed, cleaned and reinserted.

ProFile (Control)

As a control for the shaping outcomes achieved with the newer instrument systems, the students were asked to prepare one last mesiolingual canal in a third 3D-printed mandibular molar using the first-generation rotary system they were familiar with: ProFile .04 (Dentsply Maillefer). The canal was also scouted using size 10 K-File. Subsequently, preparation was performed starting with the size 45, .04-tapered instrument in a crown-down manner (Senia *et al.* 1996). Each instrument was advanced in the canal until resistance was felt. The canal was then irrigated as described above, and the next smaller instrument in the sequence (size 40, .size 35, size 30, size 25, size 20, and 15; all with an .04 taper) was used until three quarters of the working length were reached. Subsequently, a glide path to working length was prepared using to a size 15 K-File. The crown-down preparation was then continued until the first rotary instrument reached working length. Finally, the canal was enlarged apically, reverting the instrument sequence from small to large at working length.

Questionnaires

To assess the subjective experience of the students with the 2 systems under investigation, a questionnaire was completed after instrumentation of each tooth. The questionnaire asked for a 1-4 score rating of these features: controllability, cutting efficiency, sequence designation, file size designation, and length designation. In addition, the students were asked to note any specific points they deemed problematic with the system they just used. After instrumentation of the third canal using the ProFile system, a second type of questionnaire was handed to the students regarding their overall preference regarding the above features between all 3 systems. More than one system per parameter could be listed as “preferred” if students were undecided.

Assessment of shaping outcomes

The time each student took to shape each canal to a size 40 with a .04 taper was noted. Irrigation time between instruments was included in this assessment. Failed procedures (instrument fractures or failure to instrument to the requested size) were noted. After completed canal preparation and irrigation the last instrument (size 40, .04 taper for both systems under investigation and the ProFile control) was brought to working length manually for the subsequent assessment of preparation quality. The molar replicas were collected, and canal transportation was assessed radiographically using the modified Luiten method (Luiten *et al.* 1995). A radiograph was taken with the size 40, .04-tapered instrument to final length, and the angulation of this instrument was compared to that of the size 10 K-file that was recorded earlier in that canal. Length control was assessed by comparing the length of the size 10 K-file to that of the final rotary, using a scale bar in the radiograph obtained after instrumentation (Fig. 1).

Data analysis

Distribution of numerical data, i.e. goodness of fit to the normal distribution, was assessed using the Shapiro-Wilk test. Normally distributed data were compared between groups using ANOVA and Tukey’s HSD, skewed counterparts using the Kruskal-Wallis analysis of variance followed by Mann-Whitney U test for individual comparisons. Categorical data were compared using Pearson’s chi-squared test or Fisher’s exact test (two-tailed) for individual comparisons. The level of statistical significance was set at $P < 0.05$.

Results

Subjective assessments

The students noted their impressions immediately after they instrumented the first canal with either the HyFlex or the BioRace system. The same procedure was repeated after they finished the second canal, which they instrumented with the other system under investigation. As indicated, half of the students used the Hyflex system first, the other half started with BioRace. Analysis of these first two questionnaires revealed no difference between HyFlex and BioRace regarding perceived controllability and cutting efficiency (Table 1). However, sequence designation and file size designation was thought to be significantly ($P < 0.05$) better in the BioRace system. There was a marginally significant difference regarding length designation, with a tendency of the BioRace system to perform better (Table 1). Regarding specific comments, 19 out of 44 students noted that they had problems with the fourth instrument in the BioRace sequence (BR3, size 25, .06 taper). According to them, this instrument had a propensity to screw itself into the canal, and had to be cleaned several times before it reached working length.

Subsequently, all students instrumented a last mesiolingual canal in a 3D-printed molar using the ProFile .04 system, on which they had been trained, and which was used as a control. A third questionnaire was handed out after this procedure, so that the students could note their final preferences (Table 2). In this analysis it was revealed that overall, the students liked the two systems under investigation equally, but significantly ($P < 0.05$) better than the first-generation system they had known. The ProFile System could merely compete regarding file size and length designation (Table 2). Hyflex was the preferred system regarding controllability, whilst it was the worst system regarding sequence, file size and length designation (Table 2).

Objective assessments

In addition to these subjective assessments by the students, the outcome of the shaping procedures was compared between systems (Table 3). It was revealed that the two actively cutting systems under investigation were markedly ($P < 0.05$) faster than ProFile in instrumenting the mesiolingual canal in the 3D-printed tooth to a size 40 and a .04 taper, without a significant difference between them. Only one failed procedure was noted; one student wrongfully thought she fractured a HyFlex instrument and gave up on that canal (Table 3). Canal transportation was significantly ($P < 0.05$) less with the Hyflex (and the ProFile) system as compared to the BioRace system. Prior to the main study, one investigator (PB), a fourth-year dental student himself, instrumented 14 mesiolingual canals in the mandibular molar replicas using Hedström files to a size 40. This was done as a positive control. He fractured 4 instruments, and the median transportation was 4.4° (Table 3). Length control was similarly good with the two systems under investigation, while there was a tendency to lose some length with the ProFile control treatment (Table 3).

Discussion

The current comprehensive approach at comparing two instrumenting systems revealed that each system had its benefits and weaknesses. Whilst the information gathered here is far from complete, it may nevertheless be interesting to potential users and manufacturers of the rotary systems under investigation.

This investigation is limited by several facts. First, results were gained by novices. Whilst this may avoid bias from a lack in open-mindedness frequently observed with practicing dentists, the opinions/preferences and shaping outcomes of students may not necessarily reflect those of experienced practitioners. Nevertheless, it has been demonstrated in multiple studies that inexperienced operators can achieve results with rotary instruments that are comparable to those of experienced practitioners (Gluskin *et al.* 2001). In addition to respecting canal anatomy, time to shape the canal system and fracture propensity of instruments may be two objectifiable key features that are deemed important by novices and experienced users alike. Moreover, additional items for assessment were implemented: controllability, sequence, size, and file designation. This was done because 3 authors of this paper (MM, TA and MZ) have more than 15 years of individual experience in teaching rotary instrumentation to students and general practitioners. Based on this background, these features may also be decisive when it comes to preferring a specific instrument system over another. However, it goes without question that there are multiple other factors that have not been covered in this approach, such as instrument price, re-usability, versatility to solve different clinical situations, and manufacturer support. Furthermore, it should be mentioned that the students merely received oral and written instructions, no hands-on training. As has been shown (Reit *et al.* 2007) the reception of novel system differs between users who receive practical training as compared to colleagues who merely are given theoretical instructions.

A second limitation of this investigation is the fact that results were obtained in a pre-clinical environment, and in 3D-printed teeth rather than real counterparts. It should be acknowledged that the 3D-printed teeth used in this study are made from a polymer, and their mechanical features have not been compared to those of real teeth. On the other hand, 3D-printed teeth offer the advantage that they are standardized, and inter- and intra-individual comparisons of shaping outcomes are thus easily possible. Theoretically, the current results could even be compared to future studies performed with the same type of teeth. A plethora of shaping studies have been performed on canals in plastic blocks, which are made from epoxy resin, and feature round canals that are never found in nature. In this context, the use of 3D-printed teeth may be a step forward, which still awaits verification. The transportation of the canals with the rotary systems under investigation of 1° to 2° are comparable to those assessed using a similar method in real teeth instrumented with contemporary rotary systems (Bürklein *et al.* 2014). However, it should be cautioned that the assessment method here first published by Luiten *et al.* (1995) considers the apical part of the canal curvature more than the Schneider (1971) method (Günday 2005). The canal used in the current study was severely curved and narrow, as can be appreciated by the 4/14 failed attempts to instrument it to size 40 using Hedström hand files.

The two rotary systems investigated in the current study allowed a fair comparison, because in essence, they follow similar concepts, feature the same number of files, and shape to an identical final size (40) and taper (.04). They do, however, differ considerably in their nickel-titanium alloy and phase composition (Testarelli *et al.* 2011). The HyFlex system is relatively unique in that regard, because the instruments are malleable and unwind relatively quickly during their use in narrow canals. For some students this led to some uncertainty, although the feature was explained in the introduction. Furthermore, the novice users had problems when assessing whether an instrument unwound or not. According to the manufacturer, HyFlex instruments should be discarded if they do not regain their original form during re-sterilisation. Because their pitch is not constant over their working part, however, novice users and also dental assistants may have some difficulty to recognize this. In addition, several students criticized the designation of file size and number in the sequence with the HyFlex system. In this context, the BioRace System was more user-friendly, at least with novices. However, to an endodontist, these demands may be non-relevant.

The final instrument size of 40 with a .04 taper is also achieved with the ProFile .04 system, which was used as a control. This system was amongst the first nickel-titanium rotary systems that became commercially available (Haapasalo & Shen 2013). It has been taught and used for many years (Hänni *et al.* 2003). Rotary instrumentation follows the same main principles as hand instrumentation. To this end, it is important that students understand the effects of the metal alloy, tip design, cutting face, cross-section, chip space, and taper on an instrument's performance. For this reason ISO-normed rotary instruments with a relatively simple design and a uniform taper (ProFile) are used in our student courses. These instruments can easily be used in conjunction with ISO-sized hand instruments. Learning these principles enables students later to judge and assess more "modern" approaches in rotary instrumentation. In line with the current results, several studies have demonstrated that traditional and modern rotary systems result in similar shaping outcomes (Gekelman *et al.* 2009, Paqué *et al.* 2009).

The current results may be informative for dentists and manufacturers of instruments alike. In view of the latter, it can be concluded the Hyflex system has several shortcomings in designation that may be corrected relatively easily. Both systems, however, also featured perceived or objective negative properties that are not improved easily. With the HyFlex it was the propensity to unwind. With the BioRace it was the BR3, which appeared not to be an ideal step between BR2 and BR4. Also, the BioRace system slightly transported the canals. Whether the minor difference regarding this outcome between BioRace and HyFlex observed in the severely curved simulated canal under investigation is of clinical importance, however, remains elusive. It may be concluded further that both actively cutting single-length systems under investigation were preferable to the students over the traditional first-generation rotary system. This preference should be viewed critically, because both systems were new to them and obviously reached working length much quicker than the system that they were familiar with. Shaping outcomes revealed that the ProFile system could still compete with newer-generation rotary instrumentation. From a microbiological standpoint, it is also questionable whether faster is necessarily better in the context of instrumenting root canals of teeth with apical periodontitis. On the other hand, it was relatively obvious that both systems under investigation were easy to teach: after an introduction of merely 40 min, the students apparently understood their concept.

Future studies should identify the main parameters that influence the choice of instrumenting systems by dental practitioners and, perhaps more importantly, the performance of these systems when used in dental practice.

Conclusion

The HyFlex and BioRace systems each had their perceived and objectifiable advantages and disadvantages. Thy were preferred by the students over a first-generation rotary system (ProFile).

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Figure caption

From left to right: photograph of mould with the 3D-printed mandibular molar to ensure exact repositioning for radiography; radiograph with size 10 K-file at working length (23.5 mm) depicting the angle measurement that was used in this study; corresponding radiograph of a 3D-printed tooth after instrumentation with Hedström files to size 40 (positive control), and ProFile .04, size 40 (treatment control). The scale bar (panel far right with ProFile) was used to measure change in working length after instrumentation.

Table 1 Comparison between the 2 rotary systems under investigation regarding subjective parameters, assessed by the students (N = 44) in a questionnaire immediately after instrumentation where 1 indicates the best, 4 the worst score. Absolute counts of the scores are listed

	Hyflex				**BioRace**				
Score	1	2	3	4	1	2	3	4	***P* value***
Controllability	27	12	5	0	18	16	9	1	0.55
Cutting efficiency	33	10	1	0	32	12	0	0	0.21
Sequence designation	2	9	23	10	26	15	3	0	< 0.005
File size designation	5	15	17	7	16	17	10	1	< 0.05
Length designation	11	24	7	2	22	17	5	0	0.07

* Pearson's chi-squared test.

Table 2 Preference by the students (N = 44) between the 2 actively cutting rotary systems under investigation in comparison to the first-generation rotary system they knew before (ProFile)

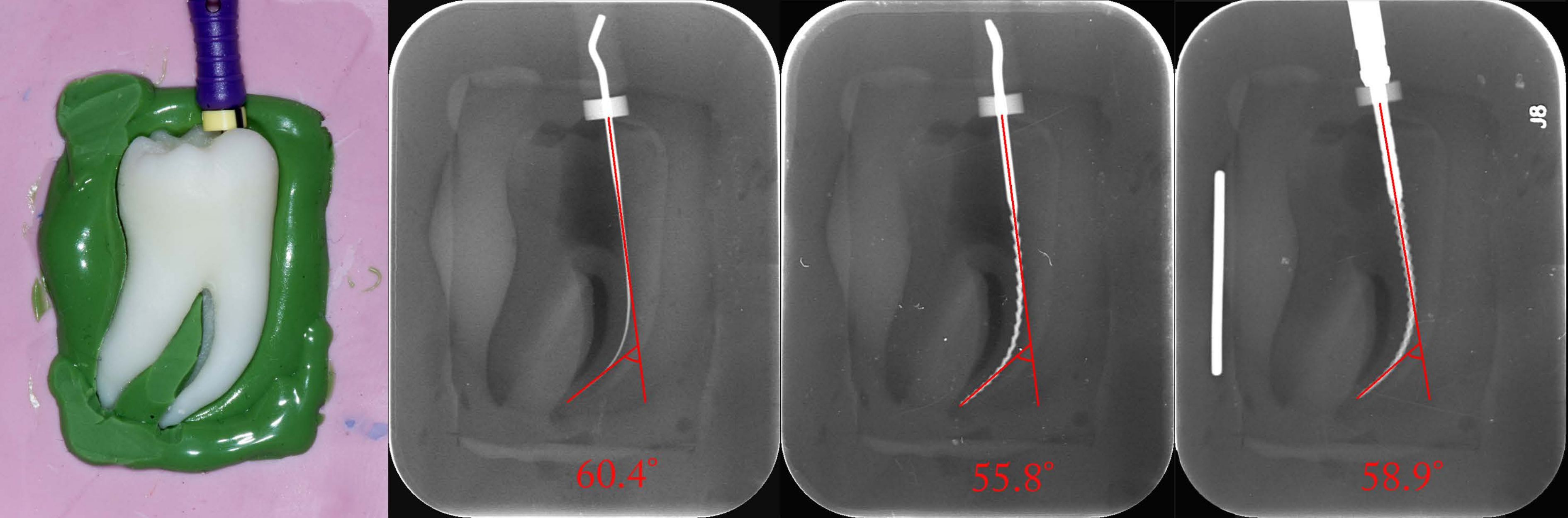
Parameter	**Hyflex**	**BioRace**	**ProFile**
Overall preference	21^{A}	22^{A}	6^{B}
Controllability	25^{A}	14^{B}	5^{C}
Cutting efficiency	24^{A}	22^{A}	0^{B}
Sequence designation	6^{B}	34^{A}	8^{B}
File size designation	5^{B}	23^{A}	20^{A}
Length designation	11^{B}	21^{A}	19^{A}

More than one preferred system per parameter could be listed if undecided. Values that share a superscript letter did not differ significantly ($P < 0.05$) between systems for a respective parameter (Fisher's exact test, two-tailed).

Table 3 Instrumenting outcomes between the 2 systems under evaluation in comparison to a rotary system (ProFile) previously used by the students ((N = 44) and Hedström hand instrumentation used as a positive control for canal transportation prior to the main experiment. Normally distributed numerical data (working length loss and time) are presented as means ± SD, skewed counterparts (canal transportation) as medians and inter-quartile ranges

Outcome	HyFlex	BioRace	ProFile	Hedström
Canal transportation (°)	1.0 (1.3) ^{A}	1.6 (1.8) ^{B}	0.7 (1.2) ^{A}	4.4 (1.4) ^{C}
Working length loss (mm)	-0.1 ± 1.1 ^{A}	0.2 ± 0.3 ^{A,B}	0.5 ± 0.3 ^{B}	ND
Time to ISO 40/.04 (s)	357 ± 126 ^{A}	395 ± 118 ^{A}	760 ± 216 ^{B}	ND
Failed procedures* per total	1/44 ^{A}	0/44 ^{A}	0/44 ^{A}	4/14 ^{B}

ND: not done.
Values that share a superscript letter did not differ significantly (P < 0.05) between systems for a respective outcome (ANOVA and Tukey's HSD for normally distributed numerical, Kruskal-Wallis followed by Mann-Whitney U test for skewed numerical, Fisher's exact test (two-tailed) for categorical data)
*Not included in numerical outcome analysis


60.4°
55.8°
58.9°
J8